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Persistent differences between native speakers and late bilinguals: Evidence from inflectional and derivational processing in older speakers*

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Previous research with younger adults has revealed differences between native (L1) and non-native late-bilingual (L2) speakers with respect to how morphologically complex words are processed. This study examines whether these L1/L2 differences persist into old age. We tested masked-priming effects for derived and inflected word forms in older L1 and L2 speakers of German and compared them to results from younger L1 and L2 speakers on the same experiment (mean ages: 62 vs. 24). We found longer overall response times paired with better accuracy scores for older (L1 and L2) participants than for younger participants. The priming patterns, however, were not affected by chronological age. While both L1 and L2 speakers showed derivational priming, only the L1 speakers demonstrated inflectional priming. We argue that general performance in both L1 and L2 is affected by aging, but that the more profound differences between native and non-native processing persist into old age.

Keywords: aging, late bilinguals, processing, morphology, inflection, derivation

Introduction

The topic of aging and bilingualism has attracted a lot of attention over the past few years. Speaking more than one language has been claimed to lead to benefits for cognitive functioning compared to monolinguals, even in the case of a non-native late-learned second language (L2) in which speakers are typically less proficient than monolinguals are in their native L1; see, for example, Bak, Nissan, Allerhand and Deary (2014); Bak, Vega-Mendoza and Sorace (2014) for advantageous effects of late-onset (non-heritage) bilingualism on cognitive measures such as selective attention and general fluid intelligence. It is "never too late", as Bak, Nissan et al. (2014) put it. One reason for the supposed cognitive advantages of bilinguals[1] could be that bilingual speakers need to switch between languages and inhibit the activation of one language when using the other, comprising activities which are thought to train general cognitive functions, such as inhibitory control, conflict resolution, and attention. In this way, bilingualism has been suggested to lead to better performance by aging bilinguals (compared to monolinguals) in tests of executive functioning (e.g., Vega-Mendoza, West, Sorace & Bak, 2015), and to even stave off symptoms of pathological memory decline, such as dementia, in older late bilinguals by several years (Woumans, Santens, Sieben, Versijpt, Stevens & Duyck, 2015). While numerous studies have investigated how aging may or may not affect bilingual speakers'

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[1] Note that we use the term 'bilinguals' to refer to speakers who acquired more than one language after birth, including in late childhood, during adolescence, or even as adults. Our focus, however, is on morphological processing in a late-acquired L2 (that is, with an onset of acquisition after the age of 6 years, see Veríssimo, Heyer, Jacob, & Clahsen, published online July 27, 2017). Where studies have examined early/simultaneous bilinguals, we will explicitly refer to those individuals as 'early bilinguals'.

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cognitive functioning, relatively little is known about the linguistic skills of older bilingual individuals compared to younger ones. Is a late-learned non-native language more vulnerable to decline or loss at old age than a native language? Do older bilinguals – perhaps due to their longer-term exposure and experience – exhibit more native-like performance in their L2 than younger L2 speakers, or do we find the same L1/L2 differences and similarities in older individuals as for younger ones?

The phenomenon we examined with respect to these questions is morphological processing, specifically the representations and processes involved in recognizing morphologically complex words during real-time language comprehension. Priming experiments have been argued to provide insights into the nature of these representations and processes; see Marslen-Wilson (2007) for review. The commonly used procedure for these experiments is to present a prime word before the target word for which a lexical (word/non-word) decision is made. The prime word may be semantically, phonologically, orthographically, and/or morphologically related to the target word. Morphological priming is found when morphologically related prime words elicit shorter lexical-decision times than unrelated prime words. Primes can be presented overtly or for a very short period of time within a forward and/or backward mask (i.e., a row of symbols such as hash marks '#####' directly preceding or following the prime word, thereby 'masking' its visibility), which, unlike in overt priming designs, does not normally permit conscious recognition of the prime. The masked priming technique has been claimed to be sensitive to morphological relatedness and to tap into the early, automatic decomposition of complex word forms more directly than other priming paradigms (e.g., Marslen-Wilson, Bozic & Randall, 2008).

Derivation and inflection in L1 and L2

A number of masked priming studies have found clear differences between L1 and L2 processing of morphologically complex words; see Jacob, Heyer and Veríssimo (published online February 1, 2017) for a recent review. The priming patterns obtained in these studies indicated non-selective morphological priming in the L1 (i.e., equally strong facilitation following derived and inflected primes) but selective priming in a non-native L2 (i.e., a robust priming effect for derivation, but no significant priming for inflection). This contrast in masked morphological priming patterns was found across different target languages (e.g., English, German, Turkish) and for a variety of different L1/L2 combinations (e.g., L1: German, Japanese, Chinese – L2 English; L1: Polish, Russian, Turkish – L2 German); see Jacob et al. (published online February 1, 2017); Kırkıcı and Clahsen (2013); Neubauer and Clahsen (2009); and Silva and Clahsen (2008). To our knowledge, there is only one study (Voga, Anastassiadis-Symeonidis & Giraudo, 2014) that reported parallel masked priming effects for derivation and inflection in L2 speakers. However, this study has a number of methodological problems, precluding any clear interpretation of the experimental findings; see Clahsen and Veríssimo (2016, pp. 690–691) for discussion.

The contrast between derivation and inflection was again obtained in a recent large-scale masked priming study (Veríssimo, Heyer, Jacob & Clahsen, published online July 27, 2017) with a large group of Turkish–German bilinguals. This study tested 91 bilingual participants from the Turkish–German community in Berlin, a large relatively homogeneous community of bilinguals, all of whom acquired Turkish from birth and German at different ages, from birth (early bilinguals) as well as after childhood (late bilinguals). The main result from this study was a reliable priming effect for derived word forms that was constant across participants irrespective of their age-of-acquisition (AoA) of German, whereas inflectional priming was found to decrease with increasing AoA. Two additional important findings were made. Firstly, the effect of AoA on inflectional priming was obtained while controlling for other potentially relevant factors, specifically proficiency in German as well as length of exposure and amount of use of German, indicating that the AoA effect on inflectional priming is independent of linguistic attainment and of amount of linguistic input. Secondly, inflectional priming was found to be subject to discontinuities at particular ages of acquisition, with facilitation from inflected forms for those bilingual participants who acquired German from birth and remaining reliable until an AoA of 6 years, but thereafter starting to decrease as AoA increased. According to Veríssimo et al. (published online July 27, 2017), this finding is indicative of a highly selective sensitive period of acquisition which constrains the way bilinguals process inflected, but not derived word forms.

From a linguistic perspective, the crucial difference between inflection and derivation is that inflection is a purely grammatical process that spells out morphosyntactic features whereas derivation is a lexical (word-formation) process that creates new lexical entries (e.g., Anderson, 1992; Stump, 2001). For processing, this means that derived word forms (being lexical entries) are potential units of storage, which, unlike morphologically simplex words, typically have internal structure (consisting, for example, of a stem and an affix). Hence, a deverbal German noun such as *Reinigung* 'cleaning, laundry' has a structured entry ($[[\text{Reinig}]_V\text{-ung}]_N$) in the German mental lexicon; see Clahsen, Sonnenstuhl and Blevins (2003). By contrast, inflected word forms are formal exponents of sets of morphosyntactic features, which form inflectional paradigms, that is, sets of forms structured by

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morphosyntactic features. The regular affix *-te* in *reinigte* ‘cleaned’, for example, simply spells out the feature [Past] of the verb *reinig(en)* ‘to clean’ in German without defining a new lexical entry. This distinction between (morpho-lexical) derivation and (morpho-syntactic) inflection is also reflected in different brain networks: a frontal left-lateralized network (including the left inferior frontal gyrus, LIFG) for inflection and a more widely distributed bilateral network (including the middle temporal gyrus, MTG) for derivation (Bozic, Szlachta & Marslen-Wilson, 2013).

The contrast between derivation and inflection obtained in bilinguals’ processing of morphologically complex words has been interpreted from this perspective. Under this view, derivational priming makes use of morpho-lexical representations (‘structured lexical entries’) from which the base stem can be accessed – for example, the verbal stem [reinig-] from the complex form $[\text{Reinin}]_{\text{V}}\text{-ung}]_{\text{N}}$. Results show that this ability is fully maintained in bilingual processing, even when the language was acquired later in life. Inflectional priming, on the other hand, engages grammatical rules or rule-like representations (‘inflectional paradigms’) from which a word form’s base stem and its morphosyntactic form-feature pairing can be accessed – for example, from the inflected form *reinigte* the verbal stem [reinig-] and a rule such as ‘*-te* = +past’. Results show that while early bilinguals make use of this kind of grammatical parsing of inflected word forms (as revealed by efficient priming), the magnitudes of inflectional priming gradually decrease with an increasing age of acquisition of a non-native language. Veríssimo et al. (published online July 27, 2017) attribute this to a sensitive period for the development of inflectional systems, suggesting that paradigm-based learning mechanisms are progressively compromised after age 6 and that, instead, learners resort more and more to memorizing and processing inflected forms as whole chunks.

Age and language processing

Returning to the topic of age and bilingualism, we need to distinguish effects of CHRONOLOGICAL AGE from effects of AGE-OF-ACQUISITION on language processing. As regards the former, high chronological age may have negative effects on language performance, due to cognitive aging, or positive effects, due to increased experience and exposure. In addition, age-of-acquisition, that is, the age at which a particular skill was first learnt, may also influence performance later in life or even throughout the lifespan.

Consider first potential effects of chronological age. Old age comes with a number of cognitive and neurophysiological changes that are likely to influence language performance negatively. Older people are typically slower in performing a given task than younger ones, and older people may exhibit reduced attention, executive, and memory skills compared to younger individuals. A number of findings from psycholinguistic studies with L1 speakers indeed seem to be attributable to general cognitive decline and slowing at old age, for example, increased numbers of errors in acceptability and verification judgements (Goral, Clark-Cotton, Spiro, Obler, Verkuilen & Albert, 2011), longer response times in lexical-decision and judgment tasks (Caplan & Waters, 2005; Duñabeitia, Marin, Avilés, Perea & Carreiras, 2009; Reifegerste & Felser, 2017; Reifegerste, Hauer & Felser, 2017), greater word-finding difficulties (Meinzer, Flaisch, Seeds, Harnish, Antonenko, Witte, Lindenberg & Crosson, 2012a; Meinzer, Seeds, Flaisch, Harnish, Cohen, McGregor, Conway, Benjamin & Crosson, 2012b), a higher rate of tip-of-tongue incidents (Cross & Burke, 2004; Rastle & Burke, 1996; Shafto, Burke, Stamatakis, Tam & Tyler, 2007), and an increase in hesitations and pauses during language production (Kemper, Herman & Lian, 2003). Studies with bilinguals have shown a similar decrease in L2 performance at old age, for example, with respect to vocabulary size and to speed and accuracy of lexical access of simple words in naming and fluency tasks (see, e.g., Bialystok, Craik & Luk, 2008, who present data from a mixed group of younger and older early and late bilinguals). Furthermore, additional (neuro-)cognitive resources need to be recruited at old age for language processing. Tyler, Shafto, Randall, Wright, Marslen-Wilson and Stamatakis (2010), for instance, found that even in a case in which behavioral outputs in a word-monitoring task were parallel for older and younger (L1) subjects, older individuals required increased compensatory activity in right fronto-temporal brain regions to achieve their high performance. Prehn, Taud, Reifegerste, Clahsen and Flöel (2018) made a similar point for bilinguals, reporting that old-age late bilinguals (compared to L1 controls) not only produced more errors in a grammaticality-judgement task, but also showed increased activity in the bilateral medial brain regions while performing the task; see also Abutalebi and Green (2016) and Green and Abutalebi (2013).

On the other hand, not everything gets worse at old age. Older people have gained more experience than younger people over the course of their life, which may lead to positive effects on language performance, such as age-related increases in accuracy (Allen, Madden & Crozier, 1991; Ratcliff, Thapar, Gomez & McKoon, 2004; Reifegerste, Meyer & Zwitserlood, 2017). Indeed, Ramscar, Hendrix, Shaoul, Milin and Baayen (2014) even attributed age-related slowing in linguistic tasks to more experience, in this case to increased vocabulary size at old age. Backed up by simulation models, they argued that older speakers tend to respond not only more slowly but also more accurately in lexical-decision tasks than

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younger individuals because the former have acquired a multitude of words over the course of their lifetime, which leads to more competition between lexical candidates. Obviously, this also holds for (early as well as late) bilinguals. Older bilinguals generally have had more exposure to a second or third language than younger ones, which may lead to larger vocabularies possibly yielding slower but more accurate linguistic performance in older than in younger bilinguals.

In addition to effects of chronological age on performance in linguistic and non-linguistic tasks, the age at which a particular skill emerged or was first learnt may also affect performance later in life. Talents, aptitudes, and abilities that developed early in life are likely to be preserved at old age, often more so than later-learnt skills (Ackerman, 2013; Ericsson, Krampe & Tesch-Römer, 1993). Such developmental effects have also been reported for linguistic abilities. Age of acquisition (of object names) was, for example, found to significantly affect object naming in older adults (more so than word length, frequency, etc.), with better performance on early-learnt words than on late-learnt ones (Hodgson & Ellis, 1998; see also Poon & Fozard, 1978). From this perspective, we would also expect to find persistent differences into old age between L1 speakers, who acquired a given language from birth, and late bilinguals (L2 speakers), who learnt the same language later in life. Evidence for this comes from studies comparing old-age L1 and L2 speakers relative to younger L1 and L2 speakers. With respect to a range of lexical measures of morphologically simplex words (viz., vocabulary size, verbal fluency, picture-naming accuracy), a number of studies reported overall weaker performance in L2 speakers (compared to L1 speakers), a contrast that was found to be parallel for younger and older participants (e.g., Bialystok et al., 2008; Gollan, Montoya, Cera & Sandoval, 2008). As regards grammatical processing, a comparison that includes these four participant groups (younger and older L1 and L2 speakers) is (to our knowledge) available from just one study, Clahsen and Reifegerste (2017). Their experiment 1 presents data from a morphological cross-modal priming experiment (auditory primes, visual targets) with both old- and young/middle-age L1 and L2 speakers of German testing for priming effects from regular and irregular participles. The results are mixed and do not provide decisive evidence for or against the hypothesized persistence of L1/L2 differences at old age. Priming effects for irregular participles that were present for both young/middle-age L1 and L2 speakers disappeared in the older participant groups, both in the L1 and the L2, which was attributed to an age-related decline of memory traces for lexically stored irregular forms in both the L1 and the L2. Regular participles, on the other hand, showed large ('full') priming effects of the same magnitude as repetition priming in the young L1 group and reduced ('partial') priming effects in the young L2 group. These full priming effects were interpreted in terms of stem repetition, while the partial priming effects were argued to be due to lexical relatedness: Younger L1 speakers directly accessed the stem contained in regular participles through grammatical computation, while younger L2 speakers processed regular participles as stored lexical entries, allowing only for indirect stem activation via associative links between stored forms. For the older participant groups, however, the repetition-priming condition with identical prime and target words did not yield any facilitation, neither in the L1 nor the L2 – an unexpected finding that made it impossible to determine whether the full versus partial contrast found for regular inflectional priming in younger L1 versus L2 speakers was still present at old age.

The present study

Against this background, the current study presents new findings on the topic of bilingualism and aging. Our focus is on grammatical abilities, specifically the representation and processing of different kinds of morphologically complex words (derivation vs. inflection). We ask how MORPHO-LEXICAL priming from highly productive derived word forms and MORPHO-SYNTACTIC priming from fully regular inflected word forms are affected in both older L1 and older L2 speakers. One relevant factor is age-related decline, which has been shown to reduce priming effects from irregularly inflected word forms in older individuals' L1 and L2 (Clahsen & Reifegerste, 2017). If age-related decline affects morphology more generally, we should find reduced priming effects for older adults (compared to young and middle-age ones) for derived and inflected words in both the L1 and L2.

Another potentially relevant factor is exposure. It is conceivable that due to their larger linguistic experience, older people not only have larger vocabularies than younger individuals for simplex words, but also for morphologically complex words. If this is the case, we should find (pace Ramscar et al., 2014) slower but more accurate performance on derived and inflected words in older than in younger individuals, in both the L1 and the L2.

Finally, linguistic performance at old age may be affected by how and when a particular linguistic ability was learnt, as part of L1 development during early childhood or as part of a late-learned L2. Previous research on vocabulary indicates an L1 (over L2) advantage on various lexical measures that persists into old age. If this extends to morphology, we should find L1/L2 differences seen in young and middle-age individuals (e.g., more efficient inflectional and/or derivational priming in the L1 than in the L2) to extend to older individuals.

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Table 1. *Demographic information on participants.*

		L1		L2	
Younger*	n	36		36	
	Sex	27 F, 9 M		30 F, 6 M	
		mean	SD	mean	SD
	Age	22.9	2.8	26.7	4.8
	AoA German	(birth)	–	13.4	6.1
	Exposure to German (years)	22.9	2.8	13.3	6.6
	Length of residence (years)	–	–	8.5	6.2
	Goethe Score (out of 30)	–	–	26.7	2.0
	MMSE (out of 30)	–	–	–	–
	Word-List Learning (out of 30)	–	–	–	–
Older	n	36		36	
	Sex	27 F, 9 M		19 F, 17 M	
		mean	SD	mean	SD
	Age	62.1	10.0	61.1	8.0
	AoA German	(birth)	–	19.9	8.6
	Exposure to German (years)	62.1	10.0	41.2	13.4
	Length of residence (years)	–	–	31.9	15.2
	Goethe Score (out of 30)	–	–	25.9	3.5
	MMSE (out of 30)	29.3	0.9	29.3	0.6
	Word-List Learning (out of 30)	22.7	3.1	24.3	3.1

*From Jacob et al. (published online February 1, 2017)

We adopted the design, materials, and procedure from Jacob et al. (published online February 1, 2017), a masked-priming study with young and middle-age L1 and L2 speakers of German (mean ages: 22.9 and 26.7 years, respectively). The particular advantage of Jacob et al.'s design is that it compares priming effects from derived and inflected words on the same target word (e.g., *Warnung* → *warnen* 'warning' → '(to) warn' vs. *gewarnt* → *warnen* 'warned' → '(to) warn'), which allows for direct within-participant and within-item comparisons of these two morphological processes. Using this design, we collected new masked-priming data from 72 old L1 and L2 speakers of German with mean ages of 62.1 and 61.1 years respectively. To determine potential age-related changes, we directly compared the new data from older participants to those from Jacob et al. (published online February 1, 2017).

Methods

Participants

Thirty-six older L1 speakers of German and 36 older L2 speakers of German (with English as L1) participated in the experiment. These 72 participants were compared to the data from the same number of young and middle-aged participants originally tested by Jacob et al. (published online February 1, 2017). Table 1 presents demographic details on the four participant groups.

All participants were living in Germany at the time of testing, had normal hearing and normal or corrected-to-normal vision, and reported no neurological or language-related impairments, gave their informed consent, and were paid for their participation in the study. Note that in order to keep the number of participants equal across all examined groups, four randomly chosen participants (one participant per presentation list, see Materials) were removed from the dataset of younger L1 speakers taken from Jacob et al. (published online February 1, 2017). Note also that the L2 group tested in Jacob et al. (published online February 1, 2017) had Russian as their L1, whereas the current group of older L2 speakers had English as their L1, a sample that was easier to recruit than old-age L1 Russian speakers of German. We will return to the potential role of this difference in L1 background for the priming results in the Discussion section. The L2 participants' German skills were examined using the Goethe Placement Test, a 30-item multiple-choice cloze test (www.goethe.de/cgi-bin/einstufungstest/einstufungstest.pl) assessing

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Table 2. *Overview of the materials.*

	Prime word				Target word
Morphological test condition ($n = 28$)					
	Identity	Derivation	Inflection	Unrelated	
	warnen	*Warnung*	*gewarnt*	*klein*	*warnen*
	'(to) warn'	'warning'	'warned'	'small'	
Orthographic control condition ($n = 24$)					
	Identity	Related		Unrelated	
	Kasse	*Kasten*		*Schwan*	*Kasse*
	'cash register'	'box'		'swan'	
Semantic control condition ($n = 24$)					
	Identity	Related		Unrelated	
	Stuhl	*Tisch*		*Licht*	*Stuhl*
	'chair'	'table'		'light'	

vocabulary and grammar knowledge in German. There was no significant difference in scores achieved between the younger and the older L2 speakers (means: 25.9 vs. 26.7, $t(70) = 1.17$, $p = .24$). This score corresponds to the C1 proficiency level, labelled as 'effective operational proficiency' according to the Common European Framework for Languages (CEFR; Verhelst, Van Avermaet, Takala, Figueras & North, 2009). Relative to the younger L2 speakers, the older L2 participants started learning German later in life (means: 19.9 vs. 13.4 years, $t(70) = 3.69$, $p < .0001$), had been living in Germany for a significantly longer time (means: 31.9 vs. 8.5 years, $t(70) = 8.55$, $p < .0001$), and had a significantly longer exposure to German (means: 41.2 vs. 13.3 years, $t(70) = 10.11$, $p < .0001$). We will determine how these between-group differences affected the current experimental findings.

Older L1 and older L2 speakers were also tested with the Mini-Mental State Examination (MMSE; Folstein, Folstein & McHugh, 1975), which confirmed that with a mean score of 29.3 (out of 30), our participants were not affected by any kind of pathological memory decline. In order to assess verbal memory, all older participants underwent a word-list learning test (Atkinson & Shiffrin, 1971) consisting of three rounds, in which participants were presented visually with ten words and were asked to memorize and recall as many words as possible at the end of each round ('immediate recall learning'). The total sum of words recalled (maximum: 30) was taken as a proxy of verbal memory abilities, with older L2 speakers actually performing better than older L1 speakers (means: 24.3 vs. 22.7, $t(70) = 2.18$, $p = .033$). Both the MMSE and the word-list learning task were administered in the participant's L1.

Materials

The experiment included a morphological test condition as well as semantic and orthographic control conditions. See Table 2 for an overview of the experimental conditions and an example stimulus set.

The morphological condition included 28 prime-target pairs. All target words were -*(e)n* forms of verbs (e.g., *warnen* '(to) warn'), which most typically function as a verb's citation (infinitive) form, but which in present-tense contexts with 1st and 3rd pl subjects may also function as finite verb forms (*Wir/Sie warnen dich* 'We/they warn you'). Primes were either (i) identical to the target word, (ii) the corresponding deverbal nominalization, (iii) the regular -*t* past-participle form of the same verb, or (iv) an unrelated prime. In both morphological conditions, the prime words contain three additional letters to the stem (-*ung*, *ge*-*t*), allowing the derived and inflected prime words to be matched for length. Across all prime-type conditions, prime words were also matched for word-form frequency.

Each of the two control conditions (semantic and orthographic) contained 24 experimental targets, preceded by three types of primes: identity, related, and unrelated. Targets in the semantic and orthographic sets were matched for word-form and lemma frequency to the morphological targets. The degree of overlap between orthographically related and morphologically related primes and targets was also matched. The unrelated primes in the semantic and orthographic sets were of similar length as well as word-form and lemma frequency (all ts < 1).

324 fillers were added to the 76 experimental items (28 morphological pairs, 24 orthographic pairs, 24 semantic

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pairs), with half of the targets being existing words in German and half being nonwords created by changing one to three letters of existing words. Primes and targets were nouns, verbs, and adjectives in equal proportions. The number of related items was less than 19%.

Four experimental lists were composed based on a Latin-Square design, so that each target word was presented only once to a participant. That is, for example, if a given participant saw the prime-target pair *gewarnt*-*warnen* (i.e., inflectional condition), they did not see that same target in any of the other conditions (*warnen*-*warnen*, *Warnung*-*warnen*, or *klein*-*warnen*). The lists were presented in reversed order to half of the participants. See Jacob et al. (published online February 1, 2017) for further information and the complete matching details.

Procedure

To allow for direct comparisons with the young participant groups from Jacob et al. (published online February 1, 2017), the procedures for the newly acquired data from the older participants were held parallel. Participants were tested individually in a quiet room using DMDX (Forster & Forster, 2003) for stimulus presentation and data collection. Each experimental trial started with a 500 ms blank screen followed by a forward mask consisting of hash marks (of the same length as the prime word) for 500 ms. The forward mask was followed by a prime word shown for 50 ms. The target word appeared immediately after the presentation of the prime and remained visible until the participant had made her decision, but not for more than 500 ms. Participants were asked to decide as quickly as possible whether the presented letter strings were existing German words or not by pressing either the 'YES' or the 'NO' button on a gamepad, with the dominant hand controlling the 'YES' button. Reaction-time (RT) measurements started with the presentation of the target word. If the participant did not respond within 5000 ms, the next trial started. There was no feedback on accuracy. Before the experimental session, each participant underwent a practice section consisting of 10 prime-target pairs. At the end of the experimental session, all participants were asked to describe what they saw on the screen to ensure that they were unaware of the primes. No participant reported noticing any of the prime words.

The experiment lasted approximately 15–20 minutes for each of the older participants. After the experiment, all participants underwent the MMSE and the word-list learning task, and the L2 participants additionally completed the Goethe Placement Test.

Data analysis

Data cleaning procedures were applied to the new data from the older L1 and L2 participants. We excluded timeouts (L1: 0.28 %, L2: 0.04 %), extreme latencies below 300 ms or above 1700 ms (L1: 0.21 %, L2: 0.70 %), as well as, for RT analyses only, incorrect responses (L1: 1.57 %, L2: 1.81 %). No items or participants were excluded. All RT analyses were performed on (natural-)log-transformed RTs using linear mixed-effects models with crossed random effects for participants and items (see, e.g., Baayen, Davidson & Bates, 2008) using the languageR package (Baayen, 2013) and the lme4 package (Bates, Maechler, Bolker & Walker, 2014). Similarly, accuracy rates were analyzed using generalized linear mixed-effects models (binomial family). Fixed effects were Age Group (young/old), Language Group (L1/L2), Prime Type (Identity/Derived/Inflected/Unrelated), Trial Number (continuous, centered), and Memory Score (continuous, centered). Trial Number (the position of the item within its presentation list) was included to control for trial-level effects; Memory Score was included to account for the differences between older L1 and L2 speakers in the word-list learning test. As Prime Type contained four levels, its effects were assessed through successive relevelling.

Results

Table 3 presents mean accuracy rates as well as mean RTs and standard deviations for the different experimental conditions (morphological, semantic, orthographic) and participant groups (young/old, L1/L2). Our focus here will be on the new data from the older L1 and L2 speakers. Comparisons with Jacob et al.'s (published online February 1, 2017) data from younger L1 and L2 speakers will be presented subsequently.

Across all conditions, analyses of ACCURACY RATES yielded a main effect of Age Group ($\beta = -1.1915$, $SE = 0.1667$, $z = -7.15$, $p < .001$), with older speakers showing overall higher accuracy rates than younger speakers. Language Group did not affect accuracy rates ($\beta = -0.0898$, $SE = 0.1664$, $z = -0.54$, $p = .589$), and neither did the interaction between Language Group and Age Group ($\beta = -0.0297$, $SE = 0.3327$, $z = -0.09$, $p = .929$). There were no main effects of or interactions between Prime Type and Language Group for either the morphological, the orthographic, or the semantic set (all $ps > .1$).

Analogous omnibus analyses (i.e., across prime-type conditions) of the RT DATA yielded main effects of Language Group ($\beta = 0.1790$, $SE = 0.0252$, $t = 7.12$) and Age Group ($\beta = -0.0513$, $SE = 0.0252$, $t = -2.04$), due to significantly slower responses for L2 than for L1 speakers and significantly slower responses for older than for younger individuals. There was no interaction between Age and Language Group ($\beta = -0.0447$, $SE = 0.0503$, $t = -0.89$).

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Table 3. *Overview of RTs and accuracy rates for the morphological, semantic and orthographic set for the four groups. (Note that the means and SDs for the younger L1 group differ slightly from the ones reported in Jacob et al. (published online February 1, 2017) because we removed the data from 4 participants. The removal of these participants did not affect the significance of any of the effects.)*

Morphological Set

			L1				L2			
			identity	derived	inflected	unrelated	identity	derived	inflected	unrelated
Younger*	RT	mean	569	618	609	638	711	725	751	767
		(SD)	(126)	(119)	(114)	(133)	(151)	(150)	(172)	(154)
	accuracy		96.0 %	97.2 %	96.0 %	93.3 %	96.4 %	96.4 %	95.2 %	93.7 %
Older	RT	mean	588	615	622	647	704	751	782	778
		(SD)	(105)	(133)	(138)	(115)	(154)	(162)	(175)	(181)
	accuracy		99.2 %	99.6 %	99.2 %	98.4 %	99.2 %	97.6 %	98.8 %	98.0 %

Semantic set

			L1			L2		
			identity	related	unrelated	identity	related	unrelated
Younger*	RT	mean	551	591	595	635	685	685
		(SD)	(113)	(100)	(96)	(118)	(122)	(116)
	accuracy		92.7 %	96.5 %	94.1 %	96.5 %	94.9 %	98.2 %
Older	RT	mean	577	611	621	704	747	746
		(SD)	(160)	(150)	(155)	(165)	(192)	(151)
	accuracy		99.2 %	97.2 %	96.9 %	97.6 %	97.6 %	99.7 %

Orthographic Set

			L1			L2		
			identity	related	unrelated	identity	related	unrelated
Younger*	RT	mean	546	600	597	636	683	701
		(SD)	(108)	(98)	(90)	(122)	(114)	(122)
	accuracy		96.2 %	95.1 %	96.9 %	98.2 %	94.2 %	98.6 %
Older	RT	mean	569	630	623	689	752	756
		(SD)	(150)	(151)	(146)	(153)	(185)	(163)
	accuracy		99.2 %	99.0 %	98.6 %	98.6 %	96.9 %	97.2 %

*From Jacob et al. (published online February 1, 2017)

To analyze the RT data from the MORPHOLOGICAL SET, a model which included a three-way interaction between Age Group (young/old), Language Group (L1/L2), and Prime Type (identity/derived/inflected/unrelated) was fitted to the data. This full model was then compared to a model which included the three relevant lower-level two-way interactions, in order to examine whether any priming effects were different for the two age groups and/or for L1 versus L2 speakers. Model comparisons using the anova() function revealed that including the three-way interaction between Age Group, Language Group and Prime Type significantly improved the fit of the model [$\chi^2(3) = 8.63$, $p = .035$]. This three-way interaction was further explored firstly, by a detailed within-group analysis of the newly acquired data from older L1 and L2 speakers, and secondly by a comparison to the data from Jacob et al. (published online February 1, 2017) to determine potential effects of aging on morphological priming in L1 and L2 speakers.

Consider first Table 4, which presents a mixed-effects model fitted to the RT data from our older groups of participants.

The results of the model show that for the L1 group (see Table 4: 'Relevelled for L1'), both derived and inflected primes yielded significantly faster responses to targets than unrelated primes and significantly slower responses compared to the identity condition. Crucially, RTs for items following derived and inflected primes did not differ from one another in the L1 group. By contrast, derived (but not inflected) primes produced significantly shorter RTs compared to unrelated primes in the L2 group; see Table 4:

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Table 4. *The best-fit model for the RT data from the morphological set for the older participants.*

Random effects:		Variance	SD	
subject	(Intercept)	0.0203	0.1426	
item	(Intercept)	0.0017	0.0410	
Residual		0.0236	0.1537	
Fixed effects:		β	SE	t-value
Intercept		6.4500	0.0280	230.75
trial number		-0.0001	0.00003	-1.85
memory score		0.0010	0.0052	0.18
Relevelled for L1:				
prime type [identity-derivation]		0.0559	0.0142	3.94
prime type [identity-inflection]		0.0533	0.0142	3.76
prime type [identity-unrelated]		-0.1083	0.0142	-7.62
prime type [derivation-inflection]		-0.0026	0.0142	-0.18
prime type [derivation-unrelated]		-0.0524	0.0142	-3.69
prime type [inflection-unrelated]		-0.0550	0.0142	-3.87
Relevelled for L2:				
prime type [identity-derivation]		0.0621	0.0139	4.48
prime type [identity-inflection]		0.0997	0.0138	7.24
prime type [identity-unrelated]		-0.0996	0.0139	-7.19
prime type [derivation-inflection]		0.0376	0.0139	2.71
prime type [derivation-unrelated]		-0.0375	0.0139	-2.69
prime type [inflection-unrelated]		0.0001	0.0139	0.01
Effects of language group (L1/L2) on prime type:				
prime type [identity-inflection]		0.0464	0.0198	2.35
prime type [identity-derivation]		0.0062	0.0198	0.31
prime type [identity-unrelated]		0.0087	0.0199	0.44
prime type [derivation-inflection]		0.0402	0.0198	2.03
prime type [inflection-unrelated]		0.0551	0.0198	2.78
prime type [derivation-unrelated]		0.0149	0.0199	0.75
Effects of language group (L1/L2) on RTs:				
identity condition		0.1957	0.0379	5.16
derivation condition		0.2019	0.0379	5.33
inflection condition		0.2421	0.0379	6.38
unrelated condition		0.1870	0.0380	4.92

'Relevelled for L2'. Furthermore, direct comparisons for the two language groups (see Table 4: 'Effects of language group (L1/L2) on prime type') revealed that the amount of inflectional priming was significantly larger in the L1 than the L2 group, whereas there were no reliable between-group differences for derivational priming. Finally, as mentioned above, overall RTs for L2 speakers were found to be significantly longer compared to L1 speakers; see Table 4: 'Effects of language group (L1/L2) on RTs').

Consider next direct comparisons of the RT data from the morphological set for the old and the young participant groups. As the younger L2 participant group had a lower mean AoA than the older speakers, we first performed a preliminary analysis to assess whether AoA interacted with Prime Type. This interaction was not significant [$\chi^2(3) = 4.1645$, $p = .244$], indicating that AoA did not affect priming patterns in our data set. Subsequently we fitted separate models to the data from the (younger vs. older) L1 and L2 groups; see Table 5. The model for the L1 GROUPS did not reveal any significant effects of Age Group on RTs in any of the four prime type conditions (all *t*s < 0.86) or on priming effects (all *t*s < 1.57), indicating that the derivational or inflectional priming effects remain stable at older age. The model

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Table 5. *The best-fit model for the RT data from the morphological set.*

L1 groups			
Fixed effects:	β	SE	t-value
Intercept	6.4340	0.0300	214.21
trial number	-0.00005	0.00003	-1.52
Effects of age group (younger/older) on RTs:			
identity condition	0.0346	0.0402	0.86
derivation condition	0.0020	0.0402	0.05
inflection condition	0.0128	0.0402	0.32
unrelated condition	0.0187	0.0403	0.47
Effects of age group (younger/older) on prime type:			
prime type [identity-inflection]	-0.0218	0.0208	-1.05
prime type [identity-derivation]	-0.0326	0.0207	-1.57
prime type [identity-unrelated]	0.0159	0.0209	0.76
prime type [derivation-inflection]	0.0108	0.0207	0.52
prime type [inflection-unrelated]	-0.0059	0.0209	-0.28
prime type [derivation-unrelated]	-0.0167	0.0208	-0.80
L2 groups			
Fixed effects:	β	SE	t-value
Intercept	6.6110	0.0328	201.74
Effects of age group (younger/older) on RTs:			
identity condition	0.0080	0.0426	0.19
derivation condition	0.0501	0.0426	1.18
inflection condition	0.0537	0.0426	1.26
unrelated condition	0.0259	0.0427	0.61
Effects of age group (younger/older) on prime type:			
prime type [identity-inflection]	0.0457	0.0210	2.17
prime type [identity-derivation]	0.0421	0.0210	2.00
prime type [identity-unrelated]	-0.0179	0.0211	-0.85
prime type [derivation-inflection]	0.0036	0.0211	0.17
prime type [inflection-unrelated]	0.0278	0.0212	1.31
prime type [derivation-unrelated]	0.0242	0.0212	1.14

fitted to the data from the L2 GROUPS shows that the derivational priming effect was parallel for the two age groups ($t = 1.14$) and that Age Group did also not affect facilitation (or rather the lack thereof) for inflectionally related prime-target pairs ($t = 1.31$). On the other hand, comparisons of morphological primes to identity primes revealed significant effects of Age Group, with the older L2 speakers showing significantly shorter target RTs after identity than after morphologically related primes ($t = 2.17$ and $t = 2.00$, respectively). Taken together, these findings indicate that while morphological priming effects are parallel across the two age groups, the magnitude of repetition priming increases with age, but only in the older L2 participant group.

Finally, we fitted mixed-effects models to the RT data from the ORTHOGRAPHIC and SEMANTIC control conditions, again initially on the newly acquired data from older L1 and L2 speakers, followed by a comparison to the data from Jacob et al. (published online February 1, 2017). The main finding from these models was that the semantically and the orthographically related primes did not elicit any reliable facilitation compared to unrelated items in either the older L1 ($t = -1.35$ and $t = 0.84$, respectively) or the older L2 group ($t = -0.62$ and $t = -0.06$, respectively). Detailed model outputs are shown in the Appendix; see Tables S1 and S2 in the Supplementary Materials (Supplementary Materials). Secondly, there were reliable repetition-priming effects, with significantly shorter target RTs after identity primes than after unrelated ones in both the L1 and the L2 groups (all $ts > 4.73$). Thirdly, the L2 group had significantly longer RTs than the L1 group in all prime type conditions (all $ts > 5.66$).

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That the presentation of semantically or orthographically related primes did not lead to any facilitation effects in older L1 and L2 participants replicates the findings by Jacob et al. (published online February 1, 2017) for younger speakers. Taken together, we found priming effects for inflection and derivation, but no semantic or orthographic priming effects, indicating that the priming effects we obtained are genuinely morphological in nature, rather than due to semantic or surface-form overlap between primes and targets.

Discussion

The present study investigated how aging affects non-native language processing, an understudied area of research – particularly with regards to grammar –, which is of interest to a number of more general issues. One common side effect of aging is cognitive decline, to which a non-native L2 may be more susceptible than a native L1, as the former was acquired later in life than the latter. On the other hand, aging also leads to more exposure to the target language, and this may render performance in older L2 speakers more native-like compared to younger individuals (similar to what has been proposed – within younger speakers – by experience-based accounts of L2 processing). Alternatively, it is of course conceivable that aging has little effect on linguistic performance and that L1/L2 differences seen for younger speakers simply persist into old age. We addressed these questions by investigating morphological processing in older L1 and L2 speakers of German. The specific diagnostic we used was the processing of inflected and derived words, a grammatical phenomenon for which several previous studies with younger groups of participants obtained a robust L1/L2 contrast: L1 speakers showed significant priming effects for both derivational and inflectional priming, while L2 speakers showed reliable priming effects for derived word forms, but no or smaller effects for inflected forms.

The findings from the current study with older participants are two-fold. One set of findings concerns effects of aging on GENERAL MEASURES OF LANGUAGE PERFORMANCE in both L1 and L2 speakers – that is, how accurate and how fast younger and older L1 and L2 speakers are at performing a linguistic task –, while the second set of findings refers more SPECIFICALLY to morphological processing – that is, the priming patterns exhibited by younger and older L1 and L2 speakers for derivations and inflections. Regarding general measures, both groups of older speakers were more ACCURATE in their 'lexical' (word/non-word) decisions than younger individuals in the same task, a familiar finding from previous lexical-decision studies with L1 speakers (Allen et al., 1991; Ratcliff et al., 2004; Reifegerste et al., 2017) that has been attributed to older speakers' larger vocabularies, presumably because they have been exposed to a larger number of words over the course of their (longer) lifetime (Bialystok & Luk, 2012; Burke & Shafto, 2008; Facal, Juncos-Rabadán, Rodríguez & Pereiro, 2012). For L2 speakers, on the other hand, there is much less research on this topic, with – to our knowledge – only two studies on aging and L2 lexical decision (Goral, Libben, Obler, Jarema & Ohayon, 2008; Johns, Sheppard, Jones & Taler, 2016), which did not report any effects of aging on accuracy rates. The current data set did reveal an age contrast, with significantly higher accuracy rates in older than in younger L2 speakers. We attribute this difference to longer exposure to the L2 for older than for younger individuals – in the same way as for L1 speakers. Another general performance measure, namely, participants' *RTs*, also revealed effects of aging, with both older L1 and older L2 speakers exhibiting longer RTs than their younger counterparts. For the L1 speakers, this finding is in line with previous studies reporting age-related slowing in lexical-decision times (Allen, Madden, Weber & Groth, 1993; Cohen-Shikora & Balota, 2016; Madden, 1992; Ratcliff et al., 2004; Reifegerste et al., 2017). For L2 speakers, the two aforementioned previous studies yielded different results. While Goral et al. (2008) did not obtain any RT differences between younger and older participants in their L2, Johns et al. (2016) found longer RTs in older than in younger bilinguals, in line with our findings. The sources of such age-related increases in RTs are still debated. One account holds that longer RTs in language tasks result from declining cognitive resources (Lawrence, Myerson & Hale, 1998; Lima, Hale & Myerson, 1991; Salthouse, 2000). Alternatively, Ramscar et al. (2014) suggested that an age-related increase in vocabulary size may yield not only higher accuracy rates in lexical-decision tasks but also longer RTs, because searching through a larger lexicon may be more time-consuming as more potential candidates are available and compete with each other. Our finding of longer RTs in older L1 and L2 speakers is consistent with both accounts.

A second set of findings from the present study concerns the question of how aging affects morphological processing, in our case priming patterns for derived and inflected word forms. Regarding this question, the main outcome from the present study is a native/non-native (L1/L2) contrast. While older L1 speakers showed efficient priming for both inflected and derived forms, older L2 speakers showed priming effects only for derivation, but not for inflection. This finding replicates the contrast previous studies found for younger L1 and L2 speakers (Jacob et al., published online February 1, 2017; Kırkıcı & Clahsen, 2013; Neubauer & Clahsen, 2009; Silva & Clahsen, 2008; Veríssimo et al., published online July 27, 2017). Indeed, the direct statistical comparison with Jacob et al.'s (published online February 1, 2017)

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data from younger L1 and L2 speakers, who underwent the same masked-priming experiment, revealed the same priming patterns for both age groups, indicating that the L1/L2 contrast between derivational and inflectional priming is not only robust across studies, but also persists into older age. We conclude that the priming patterns for derivation and inflection are not affected by chronological age, but instead by age of onset of acquisition. Inflectional priming persists into older age, but only in a language that was acquired as an L1 during childhood. Derivational priming is also maintained at older age, but unlike inflectional priming, it is present even in speakers that have acquired the target language later in life as an L2.

How can the observed similarities and differences we obtained in the present study for older L1 and L2 speakers be explained in comparison to the performance of younger L1 and L2 speakers? Consider first non-linguistic factors related to aging, specifically cognitive decline, additional experience, and more exposure. While these factors may indeed explain differences between younger and older individuals with respect to GENERAL measures of language performance (such as an increase in accuracy rates and overall RTs as well as a potential speed-accuracy trade-off) as laid out above, it is hard to see how the more SPECIFIC derivation-inflection split in the L2 priming results is to be accounted for in these terms. The kinds of inflected word forms we tested, that is, regular participle forms such as *gewarnt* 'warned' are highly common in German usage and not cognitively more demanding for older individuals than corresponding derived word forms such as *Warnung* 'warning'. If they were more demanding for older individuals, we should have found a derivation-inflection split, not only in the L2 data, but also in the L1 priming patterns. Instead, the older L1 speakers showed the same priming effects for both inflected and derived word forms as the younger participants.

As regards experience and exposure, recall that our older L2 participants had an average of 27.9 years of additional exposure to German compared to Jacob et al.'s (published online February 1, 2017) younger participants (see Table 1). Yet, their massively longer exposure did not render the older L2 speakers' processing of grammatical morphology (viz., inflection) more L1-like than that of younger L2 speakers on the same experiment.

A more likely cause for the contrast we found is linguistic differences between derivational and inflectional morphology, specifically the difference between MORPHO-LEXICAL derivation and MORPHO-SYNTACTIC inflection. The basic difference between derivation and inflection is that derivational processes yield new words, while inflection spells out grammatical features. To capture this contrast, the output of productive derivational processes may be conceived of as a 'unit of storage' represented in the mental lexicon through structured lexical entries, for example, $[[\text{Warn}]_{\text{V}}\text{-ung}]_{\text{N}}$ 'warning'. The output of regular inflectional processes, by contrast, are not 'units of storage', but instead result from a grammatical rule that spells out morphosyntactic features, for example, *warn* + [PAST] → *warnte* 'warned'. Previous research suggests that the ability to extract inflectional rules from the input is progressively compromised after early childhood and that, as a result, inflection is particularly difficult to acquire for L2 learners, for instance, due to impairments in the representation or use of morphosyntactic features (Blom, Polišenská & Weerman, 2006; Johnson & Newport, 1989; Meisel, 2013; Prévost & White, 2000). Furthermore, Veríssimo et al. (published online July 27, 2017) found inflection not to be efficiently deployed in the recognition of morphologically complex word forms when L2 acquisition starts relatively late in life (after the age of around 6 years). Veríssimo et al. (published online July 27, 2017) attributed this contrast to a selective sensitive period which constrains the acquisition of a language's inflectional system (the rules of which express morphosyntactic information and are paradigmatically organized), but not of its derivational system (which yields stored lexical entries). In line with this account, we found that inflectional priming persists into older age, provided the language in question was acquired as an L1 during childhood[2]. The lack of stem-priming effects for inflected words in L2 processing indicates reduced sensitivity to an inflected form's morphosyntactic structure, which may instead be represented and processed as full forms in a late-learned non-native language. Apparently, MORPHO-SYNTACTIC PROCESSING as revealed by inflectional priming effects functions efficiently in the L1, but not in a late-learned L2. The robust derivational priming effect that was seen in both younger and older L2 speakers, on the other hand, indicates intact MORPHO-LEXICAL processing of derived forms. Both groups of L2 speakers efficiently access the base stem of a derived prime word in the same way as L1 speakers, yielding facilitated recognition of a target word containing the same stem.

As an alternative to this account, consider a number of NON-MORPHOLOGICAL FACTORS as potential causes of the priming patterns we found. First, as both primes and targets are presented visually, priming effects may be due to surface form properties, specifically the orthographic

[2] It is true that the L1/L2 contrast we found is consistent with the notion of a selective sensitive period (as suggested by Veríssimo et al., published online July 27, 2017) which constrains the acquisition of a language's inflectional (but apparently not of its derivational) system, after which the processing will be non-native-like, regardless of the amount of additional exposure. Note, however, that our study was not designed to address the question of when exactly language processing starts to become non-native-like. Consequently, the distribution of AoA in our sample is not well-suited to precisely delineate age bands of sensitive periods in this domain.

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and/or visual overlap between prime and target. In our prime-target pairs, the items in the derivation condition exhibited word-initial orthographic overlap whereas the items in the inflection condition had word-medial overlap, for example the letters 'w-a-r-n' in *Warnung – warnen* vs. *gewarnt – warnen*. One may thus wonder whether positional differences in the prime-target overlap between derivations and inflections led to form priming in the derivational, but not in the inflectional condition. Previous masked-priming studies have suggested that L2 speakers may be more sensitive to form-level properties of words than L1 speakers (Diependaele, Duñabeitia, Morris & Keuleers, 2011; Feldman, Kostić, Basnight-Brown, Filipović Đurđević & Pastizzo, 2010; Heyer & Clahsen, 2015). Recall, however, that neither the L1 nor the L2 speakers showed any orthographic priming for the control items, either for items with word-initial overlap (which were matched on orthographic overlap with the derived prime-target pairs) or for those with word-medial overlap (matched with the inflected prime-target pairs). We conclude from these findings that surface form properties (viz., orthographic overlap) are an unlikely cause of the priming pattern we found.

Another potentially relevant non-morphological source for priming differences is the degree of semantic relatedness between primes and targets. Note, however, that in the inflectional condition the prime and the target are forms of the same word, for example, *warnen* 'to warn' in *gewarnt – warnen*, whereas prime and target in the derived condition are closely related but still different words, with a noun as the prime and a verb as the target. Hence, if semantic overlap was at the heart of our priming effects, we should have found stronger effects for inflection than for derivation. Furthermore, we directly compared the magnitudes of priming for derived prime words with those in the semantic control condition. Recall that the prime-target pairs in both these conditions were matched with respect to semantic overlap. Yet, in both our participant groups we found derivational priming, but no priming effect in the semantic overlap condition. We conclude that our findings are indicative of a genuine morphological contrast (viz., between derivation and inflection) in L1 versus L2 processing that cannot be accounted for in non-morphological terms.

To summarize, we found effects of aging on general measures of language performance, specifically on overall RTs and accuracy scores of lexical decisions, which may be due to neuro-cognitive decline and/or more experience with the target language due to longer exposure at older age. By contrast, the more subtle differences in how L1 and highly proficient L2 speakers process derivations versus inflections were not affected by aging. Instead, we replicated the previously reported contrast between younger L1 and L2 speakers with respect to derivational and inflectional priming for groups of older L1 and L2 speakers.

Limitations and future directions

One potential limitation results from the fact that we compared a group of older L2-German speakers with *English* as their L1 to a group of younger L2-German speakers with *Russian* as their L1. Could this difference between the two groups' L1s be responsible for any of our findings? First of all, English and German share the same script, while Russian and German do not – therefore, we may have expected Russian L1 speakers to perform more slowly than English L1 speakers in our (visual) lexical decision experiment. However, we found the opposite pattern, namely shorter overall RTs for the L1 Russian than for the L1 English group. Moreover, the specific L2 morphological priming pattern (viz., priming for derivation, but not for inflection) was parallel for both the older and younger L2 groups, despite their different L1s. Secondly, English and German are typologically more closely related than Russian and German and share a larger number of cognates. Thus, one may argue that our older L2 speakers (L1: English) were more accurate than the younger L2 speakers (L1: Russian) not because they were older and had more experience with the L2 but due to the closer relationship between English and German (see Dijkstra & Van Heuven, 2002, for the role of cognates in processing). Note however, that only two of the items used in our study constitute cognates in German and English (*warnen* – '(to) warn') and *liefern* – 'to deliver'), rendering the close relationship between English and German an unlikely source of the older L2 speakers' increased accuracy. Moreover, at a more general level, German and English are related in both the derivational and the inflectional domains, making it difficult to explain the selective priming patterns we obtained in these terms. Lastly, recall that, as laid out in the Introduction, the L2 priming pattern we found has been reported in a number of previous masked priming studies with various L1/L2 combinations. For these reasons, the findings from the two age groups of L2 speakers are unlikely to be due to their different L1s.

A valid limitation of our study is that while we replicated the well-established finding that older speakers show longer RTs than younger speakers, our study was not designed to assess the underlying causes of this difference. Future studies should include measures of general (non-verbal) processing speed (e.g., the Visual Matching test or the Cross Out test; Woodcock & Johnson, 1990) and vocabulary size as covariates to examine whether age-related increases in lexical-decision times are due to cognitive decline (Lawrence et al., 1998; Lima et al., 1991; Salthouse, 2000) and/or due to an increase in experience (e.g., Ramscar et al., 2014).

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Lastly, we readily admit that the same behavioral performance may come with different degrees of neuro-cognitive effort and that older individuals or non-native speakers may have to engage additional neural and mental resources to achieve the same behavioral output as younger individuals or native speakers. To give an example, while Tyler et al. (2010) reported similar behavioral performance for younger and older speakers in their word-monitoring task, brain measures revealed activation of additional (bilateral) fronto-temporal brain regions in older speakers, which was taken as a sign of functional compensation for age-related gray-matter loss; see also Prehn et al. (2018). Further brain-imaging studies are needed to shed light on the neuro-cognitive mechanisms and resources involved in older individuals' processing of L1 and L2 morphology.

Conclusion

The present paper investigated the processing of morphologically complex words in older individuals, both in native speakers (L1) as well as in late bilinguals (L2). Although the often positive effects of lifelong bilingualism on cognitive functioning at old age have been the subject of a large number of studies, considerably less is known about what happens to the linguistic skills of L2 speakers as they get older, particularly with regards to grammatical processing. Do the mechanisms involved in L1 and L2 language processing change as people get older – and if so, how –, or do we find the same L1/L2 differences in older people as in younger speakers? The findings from the current study contribute to these research questions.

Our main result is a contrast between older L1 and older L2 speakers in their processing of derived versus inflected words. While we found derivational priming in both the L1 and the L2 speakers, reliable inflectional priming was seen only in L1 processing. This contrast in the priming patterns replicates previous results for younger L1 and L2 speakers. We conclude that these priming patterns are NOT affected by aging. Morpho-lexical priming (from derived word forms) is fully maintained in older individuals, both in their L1 and their (late-learned) L2. Morpho-syntactic priming (from regularly inflected word forms) is also operative in older L1 speakers in the same way as in younger L1 speakers, but not in a late-learned L2, neither in younger nor in older L2 speakers. An additional set of findings concerns general language performance measures, which did indeed yield effects of aging in both the L1 and the L2. We found longer lexical-decision times but higher accuracy scores for older compared to younger individuals, regardless of language status. Taken together, these findings highlight the role of both non-linguistic factors related to aging (cognitive decline, longer experience) and of genuine linguistic contrasts (inflection vs. derivation) on older people's native and non-native language processing.

Supplementary material

To view supplementary material for this article, please visit https://doi.org/10.1017/S1366728918000615

References

Abutalebi, J., & Green, D. W. (2016). Neuroimaging of language control in bilinguals: Neural adaptation and reserve. *Bilingualism: Language and Cognition, 19*, 689–698.

Ackerman, P. L. (2013). Adult Intelligence: Sketch of a theory and applications to learning and education. In M. C. Smith & T. Pourchot (eds.), *Adult learning and development: Perspectives from educational psychology* (pp. 145–158). Chicago: Lawrence Erlbaum Associates, Inc.

Allen, P. A., Madden, D. J., & Crozier, L. C. (1991). Adult age differences in letter-level and word-level processing. *Psychology and Aging*, *6*, 261–271.

Allen, P. A., Madden, D. J., Weber, T. A., & Groth, K. E. (1993). Influence of age and processing stage on visual word recognition. *Psychology and Aging, 8*, 274–282.

Anderson, S. R. (1992). *A-morphous morphology* (Vol. 62). Cambridge: University Press.

Atkinson, R. C., & Shiffrin, R. M. (1971). The control of short term memory. *Scientific American, 225*, 82–90.

Baayen, R. H. (2013). *languageR: Data sets and functions with "Analyzing Linguistic Data: A practical introduction to statistics"*. R package version 1.4.1.

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modelling with crossed random effects for subjects and items. *Journal of Memory and Language, 59*, 390–412.

Bak, T. H., Nissan, J. J., Allerhand, M. M., & Deary, I. J. (2014). Does bilingualism influence cognitive aging? *Annals of Neurology, 75*, 959–963.

Bak, T. H., Vega-Mendoza, M., & Sorace, A. (2014). Never too late? An advantage on tests of auditory attention extends to late bilinguals. *Frontiers in Psychology, 5*, 485.

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2014). *lme4: Linear mixed-effects models using Eigen and S4*. R package version 1.1-7.

Bialystok, E., Craik, F. I. M., & Luk, G. (2008). Cognitive control and lexical access in younger and older bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34*, 859–873.

Bialystok, E., & Luk, G. (2012). Receptive vocabulary differences in monolingual and bilingual adults. *Bilingualism: Language and Cognition, 15*, 397–401.

Blom, E., Polišenská, D., & Weerman, F. (2006). Effects of age on the acquisition of agreement inflection. *Morphology, 16*, 313–336.

Bozic, M., Szlachta, Z., & Marslen-Wilson, W. D. (2013). Cross-linguistic parallels in processing derivational morphology: Evidence from Polish. *Brain and Language, 127*, 533–538.

Burke, D. M., & Shafto, M. A. (2008). Language and aging. In F. I. M. Craik & T. A. Salthouse (eds.), *The handbook of*

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aging and cognition (pp. 373–443). New York: Psychology Press.

Caplan, D., & Waters, G. S. (2005). The relationship between age, processing speed, working memory capacity, and language comprehension. *Memory, 13*, 403–413.

Clahsen, H., & Reifegerste, J. (2017). Morphological processing in old-age bilinguals. In M. Libben, M. Goral & G. Libben (eds.), *Bilingualism: A framework for understanding the mental lexicon* (pp. 217–248). Amsterdam: Benjamins.

Clahsen, H., Sonnenstuhl, I., & Blevins, J. P. (2003). Derivational morphology in the German mental lexicon: A dual mechanism account. In R. H. Baayen & R. Schreuder (eds.), *Morphological structure in language processing* (pp. 125–155). Berlin: Mouton de Gruyter.

Clahsen, H., & Veríssimo, J. (2016). Investigating grammatical processing in bilinguals: The case of morphological priming. *Linguistic Approaches to Bilingualism, 5*, 685–698.

Cohen-Shikora, E. R., & Balota, D. A. (2016). Visual word recognition across the adult lifespan. *Psychology and Aging, 31*, 488–502.

Cross, E. S., & Burke, D. M. (2004). Do alternative names block young and older adults' retrieval of proper names? *Brain and Language, 89*, 174–181.

Diependaele, K., Duñabeitia, J. A., Morris, J., & Keuleers, E. (2011). Fast morphological effects in first and second language word recognition. *Journal of Memory and Language, 64*, 344–358.

Dijkstra, T., & Van Heuven, W. J. B. (2002). The architecture of the bilingual word recognition system: From identification to decision. *Bilingualism: Language and Cognition*, *5*, 175–197.

Duñabeitia, J. A., Marin, A., Avilés, A., Perea, M., & Carreiras, M. (2009). Constituent priming effects: Evidence for preserved morphological processing in healthy old readers. *European Journal of Cognitive Psychology, 21*, 283–302.

Ericsson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100*, 363–406.

Facal, D., Juncos-Rabadán, O., Rodríguez, M. S., & Pereiro, A. X. (2012). Tip-of-the-tongue in aging: influence of vocabulary, working memory and processing speed. *Aging Clinical and Experimental Research, 24*, 647–656.

Feldman, L. B., Kostić, A., Basnight-Brown, D. M., Filipović Đurđević, D. F., & Pastizzo, M. J. (2010). Morphological facilitation for regular and irregular verb formations in native and non-native speakers: Little evidence for two distinct mechanisms. *Bilingualism: Language and Cognition, 13*, 119–135.

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). "Mini-mental state": A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12*, 189–198.

Forster, K. I., & Forster, J. C. (2003). DMDX: A windows display program with millisecond accuracy. *Behaviour Research Methods, Instruments, & Computers, 35*, 116–124.

Green, D. W., & Abutalebi, J. (2013). Language control in bilinguals: The adaptive control hypothesis. *Journal of Cognitive Psychology, 25*, 515–530.

Gollan, T. H., Montoya, R. I., Cera, C., & Sandoval, T. C. (2008). More use almost always a means a smaller frequency effect: Aging, bilingualism, and the weaker links hypothesis. *Journal of Memory and Language, 58*, 787–814.

Goral, M., Clark-Cotton, M. R., Spiro, A., Obler, L. K., Verkuilen, J., & Albert, M. L. (2011). The contribution of set switching and working memory to sentence processing in older adults. *Experimental Aging Research, 37*, 516–538.

Goral, M., Libben, G., Obler, L. K., Jarema, G., & Ohayon, K. (2008). Lexical attrition in younger and older bilingual adults. *Clinical Linguistics & Phonetics, 22*, 509–522.

Heyer, V., & Clahsen, H. (2015). Late bilinguals see a scan in scanner AND in scandal: Dissecting formal overlap from morphological priming in the processing of derived words. *Bilingualism: Language and Cognition, 18*, 543–550.

Hodgson, C., & Ellis, A. W. (1998). Last in, first to go: Age of acquisition and naming in the elderly. *Brain and Language, 64*, 146–163.

Jacob, G., Heyer, V., & Veríssimo, J. (2017). Aiming at the same target: A masked priming study directly comparing derivation and inflection in the second language. *International Journal of Bilingualism*. doi:10.1177/1367006916688333. Published online by SAGE journals, February 1, 2017.

Johns, B. T., Sheppard, C. L., Jones, M. N., & Taler, V. (2016). The role of semantic diversity in word recognition across aging and bilingualism. *Frontiers in Psychology, 7*, 703.

Johnson, J. S., & Newport, E. L. (1989). Critical period effects in second language learning: The influence of maturational state on the acquisition of English as a second language. *Cognitive Psychology, 21*, 60–99.

Kemper, S., Herman, R. E., & Lian, C. H. T. (2003). The costs of doing two things at once for young and older adults: Talking while walking, finger tapping, and ignoring speech or noise. *Psychology and Aging, 18*, 181–192.

Kırkıcı, B., & Clahsen, H. (2013). Inflection and derivation in native and non-native language processing: Masked priming experiments on Turkish. *Bilingualism: Language and Cognition, 16*, 776–791.

Lawrence, B., Myerson, J., & Hale, S. (1998). Differential decline of verbal and visuospatial processing speed across the adult life span. *Aging, Neuropsychology, and Cognition, 5*, 129–146.

Lima, S. D., Hale, S., & Myerson, J. (1991). How general is general slowing? Evidence from the lexical domain. *Psychology and Aging, 6*, 416–425.

Madden, D. J. (1992). Four to ten milliseconds per year: Age-related slowing of visual word identification. *Journal of Gerontology, 47*, 59–68.

Marslen-Wilson, W. D. (2007). Morphological processes in language comprehension. In M. G. Gaskell (ed.), *The Oxford handbook of psycholinguistics* (pp. 175–193). Oxford: Oxford University Press.

Marslen-Wilson, W. D., Bozic, M., & Randall, B. (2008). Early decomposition in visual word recognition: Dissociating morphology, form, and meaning. *Language and Cognitive Processes, 23*, 394–421.

Meinzer, M., Flaisch, T., Seeds, L., Harnish, S., Antonenko, D., Witte, V., Lindenberg, R., & Crosson, B. (2012a). Same modulation but different starting points: Performance

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modulates age differences in inferior frontal cortex activity during word-retrieval. *PLoS ONE, 7*, e33631.

Meinzer, M., Seeds, L., Flaisch, T., Harnish, S., Cohen, M. L., McGregor, K., Conway, T., Benjamin, M., & Crosson, B. (2012b). Impact of changed positive and negative task-related brain activity on word-retrieval in aging. *Neurobiology of Aging, 33*, 656–669.

Meisel, J. M. (2013). Sensitive phases in successive language acquisition: The critical period hypothesis revisited. In C. Boeckx & K. Grohmann (eds.), *Handbook of Biolinguistics* (pp. 69–85). Cambridge: Cambridge University Press,

Neubauer, K., & Clahsen, H. (2009). Decomposition of inflected words in a second language. *Studies in Second Language Acquisition, 31*, 403–435.

Prehn, K., Taud, B., Reifegerste, J., Clahsen, H., & Flöel, A. (2018). Neural correlates of grammatical inflection in older native and second-language speakers. *Bilingualism: Language and Cognition, 21*, 1–12.

Prévost, P., & White, L. (2000). Missing surface inflection or impairment in second language acquisition? Evidence from tense and agreement. *Second Language Research, 16*, 103–133.

Poon, L. W., & Fozard, J. L. (1978). Speed of retrieval from long-term memory in relation to age, familiarity, and datedness of information. *Journal of Gerontology, 33*, 711–717.

Ramscar, M., Hendrix, P., Shaoul, C., Milin, P., & Baayen, H. (2014). The myth of cognitive decline: Non-linear dynamics of lifelong learning. *Topics in Cognitive Science, 6*, 5–42.

Rastle, K. G., & Burke, D. M. (1996). Priming the tip of the tongue: Effects of prior processing on word retrieval in young and older adults. *Journal of Memory and Language, 35*, 586–605.

Ratcliff, R., Thapar, A., Gomez, P., & McKoon, G. (2004). A diffusion model analysis of the effects of aging in the lexical decision task. *Psychology and Aging, 19*, 278–289.

Reifegerste, J., & Felser, C. (2017). Effects of aging on interference during pronoun resolution. *Journal of Speech, Language, and Hearing Research, 60*, 3573–3589.

Reifegerste, J., Hauer, F., & Felser, C. (2017). Agreement processing and attraction errors in aging: Evidence from subject-verb agreement in German. *Aging, Neuropsychology, and Cognition, 24*, 672–702.

Reifegerste, J., Meyer, A. S., & Zwitserlood, P. (2017). Inflectional complexity and experience affect plural processing in younger and older readers of Dutch and German. *Language, Cognition and Neuroscience, 32*, 471–487.

Salthouse, T. A. (2000). Aging and measures of processing speed. *Biological Psychology, 54*, 35–54.

Shafto, M., Burke, D. M., Stamatakis, E. A., Tam, P. P., & Tyler, L. K. (2007). On the tip-of-the-tongue: Neural correlates of increased word-finding failures in normal aging. *Journal of Cognitive Neuroscience, 19*, 2060–2070.

Silva, R., & Clahsen, H. (2008). Morphologically complex words in L1 and L2 processing: Evidence from masked priming experiments in English. *Bilingualism: Language and Cognition, 11*, 245–260.

Stump, G. (2001). *Inflectional morphology: A theory of paradigm structure*. Cambridge: Cambridge University Press.

Tyler, L. K., Shafto, M. A., Randall, B., Wright, P., Marslen-Wilson, W. D., & Stamatakis, E. A. (2010). Preserving syntactic processing across the adult life span: The modulation of the frontotemporal language system in the context of age-related atrophy. *Cerebral Cortex, 20*, 352–364.

Vega-Mendoza, M., West, H., Sorace, A., & Bak, T. H. (2015). The impact of late, non-balanced bilingualism on cognitive performance. *Cognition, 137*, 40–46.

Verhelst, N., Van Avermaet, P., Takala, S., Figueras, N., & North, B. (2009). *Common European Framework of Reference for Languages: Learning, teaching, assessment*. Cambridge: Cambridge University Press.

Veríssimo, J., Heyer, V., Jacob, G., & Clahsen, H. (2017). Selective effects of age of acquisition on morphological priming: Evidence for a sensitive period. *Language Acquisition*. doi:10.1080/10489223.2017.1346104. Published online by Taylor & Francis, July 27, 2017.

Voga, M., Anastassiadis-Symeonidis, A., & Giraudo, H. (2014). Does morphology play a role in L2 processing? Two masked priming experiments with Greek speakers of ESL. *Lingvisticae Investigationes, 37*, 338–352.

Woodcock, R. W., & Johnson, M. B. (1990). *Woodcock-Johnson Psycho-Educational Battery-Revised*. Allen, TX: DLM Teaching Resources.

Woumans, E., Santens, P., Sieben, A., Versijpt, J., Stevens, M., & Duyck, W. (2015). Bilingualism delays clinical manifestation of Alzheimer's disease. *Bilingualism: Language and Cognition, 18*, 568–574.

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